Plasma/Spacecraft Charging Effects of Space Weather

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Plasma/Charging Effects

- Solar activity affects all aspects of space environmental effects
  - micrometeoroids and debris
  - radiation belts
  - spacecraft charging & arcing
    - geomagnetic substorms
    - auroral activity
    - ionospheric plasma density and temperature
  - drag, etc.

Plasma/Charging Effects

- LEO Ionospheric Plasma Effects
  - all bodies float slightly negative (~T_e)
  - conductors on solar arrays or distributed voltages float highly negative (~90% of system voltage), but insulators float near plasma pot.
    - dielectric layers can break down (arcs)
    - solar cells can arc from cell to coverslide surface or cell to cell
  - positive conductor surfaces can collect high currents from adjacent insulators (snapover)

Plasma/Charging Effects

- LEO high inclination orbit plasma effects
  - Auroral charging (a few kV)
    - disrupts plasma measurements by biasing instruments away from plasma ground
    - buries charge inside insulators, with eventual dielectric discharges
    - leads to arcs through differential charging on surfaces with widely different capacitances (V=Q/C)

Plasma/Charging Effects

- GEO Plasma Effects
  - not severe unless geomagnetic substorm
  - all surfaces charge highly negative (10’s of kV)
    - differential charging can occur when surfaces charge to different amounts, or are differentially discharged
      - photoelectric effect
      - secondary electron emission
      - large differences in capacitance
    - arcs occur due to differential voltages (high E fields)
    - buried charge can lead to arcing

Plasma/Charging Effects

- Sustained Arcs (Super Arcs)
  - Initial arc due to spacecraft charging (>100 V)
  - Arc plasma reaches solar array strings or other surfaces more than ~50 V different
  - Initial arc evolves into sustained arc between spacecraft high voltage components
  - Arc will continue as long as current and voltage supply last - seconds or even minutes
  - Arc melts and destroys systems (like arc welder)

Plasma/Charging Effects

- Sustained Arc on EOS-AM1 (Terra) Q-Board

Plasma/Charging Effects

- GEO and Auroral Space Weather monitoring needs (priorities):
  1. Floating potential monitors (0 to -10 kV)
  2. Local charged particle flux and spectrum (100 eV to 100 keV)
  3. Solar UV and auroral emissions monitors
- LEO Space Weather monitoring needs:
  1. Local plasma density and temperature ($N_e = 10^4$-10^7 / cm^3, $T_e = 0.05$-0.25 eV)
  2. Floating potential monitors (0 to -100 V)

Plasma/Charging Effects

- Charging/Plasma Space Weather advance warning needs (priorities):
  1. 24 hr or greater geomagnetic substorm forecasts (arrival time, severity, probability of occurrence)
  2. traditional index monitoring and predictions of solar activity (R_Z, $f_{10.7}$, K_p, etc.)

Plasma/Charging Effects

- How is the SEE Charging/EMI Working Group planning to meet these needs?
  - We have our hands full with these tasks:
    - ISS Plasma Contactor monitoring software
    - Ground tests for arc thresholds and arc mitigation
    - Ground tests of spacecraft materials charging properties
    - Accurate, 3-D software to predict spacecraft charging under worst-case conditions
    - Simplified computer tools for spacecraft designers

Plasma/Charging Effects

- Instrumentation Needs to Support Our Customers:
  - Mass-produced, low mass “sensors-on-a-chip” on every (even commercial) satellite launched, to measure:
    - Vehicle “floating potential” relative to the plasma
    - Plasma collection current versus voltage to determine N_e and T_e
      - Langmuir probes or Solar Array collection currents
    - Internal charging within dielectrics
  - Data collection, handling and analysis capabilities for large constellations of instruments

Plasma/Charging Effects

- What can LWS do to meet our customers' needs?
  - Finance development, distribution, data-collection and analysis of the sensors-on-a-chip mentioned previously
  - Measure the remaining plasma/solar parameters in detail with its scientific satellites
  - Finance a dedicated "Living with a Star" Environmental Interactions program